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MEASUREMENTS OF THE VERTICAL PROFILE OF WATER VAPOR ABUNDANCE IN THE MARTIAN ATMOSPHERE FROM MARS OBSERVER. J. T. Schofield and D. J. McCleese, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109.

In October 1991, the Mars Observer spacecraft will be inserted into a nearly circular, 361 km altitude, 92.8° inclination, sun-synchronous mapping orbit around Mars. From this platform, the Pressure Modulator Infrared Radiometer (PMIRR) will employ filter and pressure modulation radiometry using nine spectral channels, in both limb scanning and nadir sounding modes, to obtain daily, global maps of temperature, dust extinction, condensate extinction, and water vapour mixing ratio profiles as a function of pressure to half scale-height or 5 km vertical resolution. Surface thermal properties will also be mapped, and the polar radiative balance will be monitored.¹

The Mars Observer spacecraft has many advantages over previous Mars missions, and compares favorably with terrestrial atmospheric mapping orbiters for measurements of atmospheric constituent profiles by remote sounding. The circular, low orbit and spacecraft 3-axis stabilization, favour high vertical resolution limb sounding. Earth experience has shown that limb sounding is essential for the unambiguous retrieval of high vertical resolution constituent profiles.^{2,3} The high orbit inclination and short orbital period give complete latitudinal coverage and provide the daily, synoptic-scale mapping of atmosphere fields achieved by terrestrial atmospheric sounders. The 2 pm sun synchronous orbit allows mapping at local times representing diurnal extremes and permits diurnal and seasonal effects to be differentiated clearly. Finally the continuous mapping period of one martian year allows the complete seasonal cycle of water to be described in detail.

Measurements of water vapour are made by filter and pressure modulation radiometry in the near wing of the ν_2 band of water vapour at 6.9 μm , and by filter radiometry in the rotation band at 46.5 μm . In its mapping mode, PMIRR uses continuous in-track limb and nadir scanning in a repetitive cycle to obtain coincident water vapour vertical profile and column abundance measurements by day and during the night. Table 1 summarizes the horizontal, vertical and temporal resolution of the individual measurements, and mapped fields. The limiting sensitivity of nadir measurements is approximately 1 pr μm in the column, whereas that of limb measurements is about 50 times better.

The precision of retrieved profiles and column abundances depends on the actual profiles of temperature, dust and water in the Martian atmosphere. Computer simulations have been used to evaluate this precision given model profiles representing a best estimate of expected conditions on Mars. Water, dust, and temperature profiles have been retrieved simultaneously using a non-linear, iterative, relaxation technique.⁴ Figures 1a and b

compare input and retrieved water vapour profiles for a two very different model atmospheres. Figure 1a uses the Viking Lander 1 temperature profile and Figure 1b a profile from the Viking radio-occultation experiment. Both models include uniformly mixed dust with an optical depth in the nadir of 0.4 at visible wavelengths. Precision is in the range 10 - 20% up to 30 km.

Figure 2 shows a retrieved water vapour cross-section corresponding to water and temperature models developed to represent the northern summer hemisphere of Mars. Again, uniformly mixed dust with an optical depth of 0.4 is included at all latitudes. The difference between input and retrieved connections is also shown. Precision is of order 10 - 20% below 20 km. Figure 3 compares input and retrieved water vapour columns in $\text{pr } \mu\text{m}$ derived from the data of Figure 2. Again the precision is of order 10 - 20%.

Retrieval simulations, of which Figures 1-3 represent a subset, show that a precision of 10 - 20% in profiles and column abundances can be expected. However, they also show that above certain limits dust degrades the results. For limb sounding, dust optical depth to the tangent point must not exceed unity in the infrared. For the surface limb path, this limit corresponds to a nadir visible optical depth of 0.4, although this can be raised to 1.5 if relative dust extinction at 6.9 and 45 μm is known. Clearly, profile measurements are not possible near the surface during dust storms, the lower boundary being 15-20 km. Column abundances can be obtained from nadir measurement provided dust nadir optical depth to the surface is less than unity. This corresponds to visible optical depths of less than 7.5, so that column abundance measurements are almost always available.

When the primary water vapour fields outlined in Table 1 are combined with the other simultaneous, co-located PMIRR measurements, further scientific objectives relating to the water cycle on Mars can be addressed. Temperature and condensate profile data allow the atmospheric saturation state to be defined, and derived wind fields make estimates of water vapour transport possible. With water vapour abundance, profile and transport data available, sources and sinks of water vapour such as surface reservoirs and airborne dust can be identified.

References

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TABLE 1.
PMIRR WATER VAPOR - MEASUREMENT AND
MAPPED FIELD RESOLUTION NOMINAL LIMB
SCAN MODE

MEASUREMENTS					
VIEW	COORDINATE	IN-TRACK (LATITUDE)	CROSS-TRACK (LONGITUDE)	VERTICAL	SAMPLING (LATITUDE)
LIMB		240 km (4°)	25 km	5 km	95 km (2°)
NADIR		6 km	5 km	COLUMN	95 km (2°)
MAPPED FIELDS ⁽¹⁾					
VIEW	COORDINATE	RATE	1 day	3 days	56 days
LIMB	LATITUDE		4°	4°	4°
	LONGITUDE		28°	10°	4°
	ALTITUDE		5 km	5 km	5 km
NADIR	LATITUDE		2°	2°	2°
	LONGITUDE		28°	10°	2°
	ALTITUDE		COLUMN	COLUMN	COLUMN

(1) BOTH DAY AND NIGHTSIDE FIELDS OBTAINED AT THIS RESOLUTION AND REPETITION RATE

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FIGURE 1A. PMIRR
RETRIEVAL OF VERTICAL PROFILE OF
WATER VAPOR

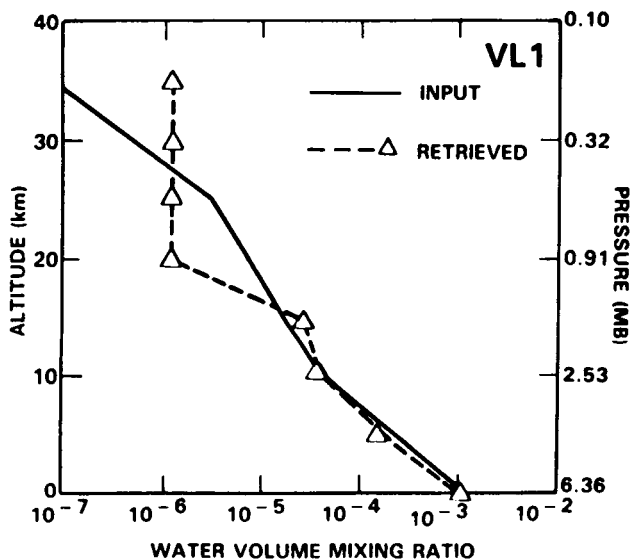


FIGURE 1B. PMIRR
RETRIEVAL OF VERTICAL PROFILE
OF WATER VAPOR

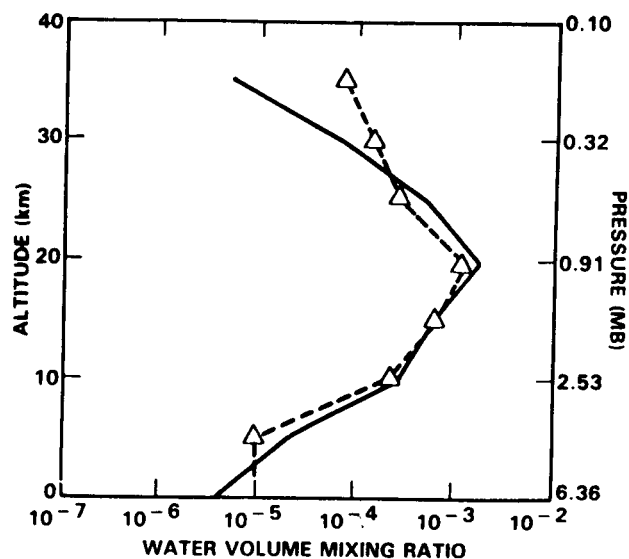


FIGURE 2.
RETRIEVED WATER VAPOR AMOUNT

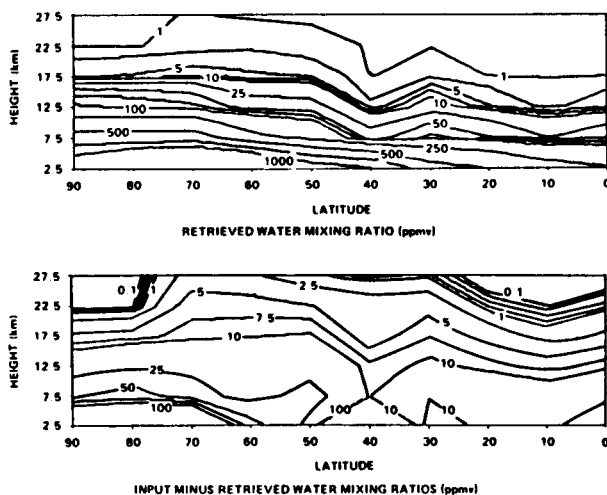


FIGURE 3. PMIRR
RETRIEVAL OF WATER COLUMN AMOUNT

